PATENT SPECIFICATION

TITLE: TENSION LEG PLATFORM HAVING MODIFIED WAVE RESPONSE CHARACTERISTICS

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BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to exploration of, drilling of, and production from offshore subterranean reservoirs. In another aspect, the present invention relates to apparatus and methods for the exploration of, drilling of, and production from offshore subterranean reservoirs.

2. Description of the Related Art

The exploration for, drilling for, and production of hydrocarbons from offshore subterranean reservoirs present quite a number of challenges. A number of different techniques have developed over the years to explore for, drill for and produce hydrocarbons from offshore reservoirs.

Economics and technology have mostly determined the water depths in which drilling and production could reasonably be conducted. Offshore production at first was conducted in shallow waters, and as technology developed and economics became more favorable, was conducted in deeper waters.

Initially, offshore well operations were conducted from fixed platforms in relatively shallow water. However, as offshore operations chased potential hydrocarbon reservoirs from shallow to deeper water the cost of fixed platforms became very expensive. In attempts to reduce expense and to conduct well operations in deep water, different systems have been proposed, such

as providing a completely submerged production station at the sea floor, providing a floating platform production system in which semisubmersible platforms are utilized, and providing a tension leg platform production system.

In general, offshore hydrocarbon production systems generally include a plurality of wells extending to undersea deposits of oil, with trees located on or above the sea floor, wherein each tree includes a plurality of valves and pipe couplings. Risers extend up from the trees to apparatus floating at/near the sea surface that has oil handling equipment.

These floating production platforms normally fall in one of two categories, either Direct Vertical Access (DVA) or Non-DVA.

A DVA systems is most suitable where the wells can be drilled, completed, and re-entered from a derrick located on the platform. They offer the convenience of easy intervention on wells when needed, and reduced drilling costs. Almost all the DVA systems installed in

the world in deepwater (waterdepth greater than 1,000 m) are either Tension Leg Platforms (TLP) or spars.

A Non-DVA system, such as a floating platform production system, is suitable for reservoirs that are spread over a large area, in which the wellheads are drilled, completed, and re-entered from a separate drilling semi-submersible or drillship. Drawbacks include the high drilling cost because of the requirement for a separate drilling vessel, and the high mobilization cost for intervention on wells.

Tension leg production system involves the use of tension leg platforms ("TLP"), such as described in U.S. Pat. Nos. 3,780,685, 3,648,638, and 3,154,039. Tension leg platforms are characterized by the absence of heave, roll or pitch in response to wave motion and thus provides opportunity for improved production efficiency and simplification of the riser design and tensioning thereof. In general, a tension leg platform consists of a platform deck supported by a buoyancy structure, a bottom anchoring structure and tension elements extending

between the buoyancy structure and the bottom anchoring structure. The buoyancy of such a platform exceeds its weight by a margin termed the excess buoyancy, which maintains the tension elements in tension.

A spar comprises a spar buoy or spar in the form of a body having a height that is a plurality of times its average width, and usually at least 5 times as tall as wide. Depending upon the width of the spar, there can be a anywhere from moderate to extensive drift in reaction to winds, currents, and waves, which may result in anywhere from moderate to excessive bending of the risers and fluid-carrying pipes therein. To keep the spar upright, its upper portion is made highly buoyant while its lower portion contains considerable ballast to weight it and thereby lower its center of gravity.

Spars are deep draft floaters (normally over 200 m draft for a typical Gulf of Mexico application). The hull is composed of a single vertical column 40 to 60 m in diameter. The truss spar is an improvement over the conventional spar, where the lower section of the hull is

truncated about 60 m below the surface, and replaced by a truss structure with horizontal plates to reduce the platform motion. Both types of spars have a large column piercing the water surface, and therefore exposed to severe wave and current loads, and risers are supported by buoyancy cans to accommodate relative displacement between the hull and the riser top.

Currently, in ultradeep water (water depths greater than 1,500 meters), the only viable system is the spar. However, the main drawbacks of spars include: the large displacement, and therefore cost of the hull; the large lateral loads that require a substantial mooring system; the buoyancy cans because of their cost, installation and operational issues, and health, safety and environment concerns; and the tendency of the hull to experience vortex-induced vibrations (VIV) because of its circular shape.

The complexity of production from ultradeepwater (water depths greater than 1,500 meters) is best understood by examining the wave environment. First, a

substantial amount of the wave energy is concentrated in the first 100 meters of water depth. Second, the frequency of the wave energy is concentrated between 6 and 15 seconds.

With a TLP, the problem is one of anchoring the TLP to provide sufficient stiffness so that the TLP will have a heave resonance generally less than the 6 to 15 second range, preferably less than 4 seconds. For example, at 1200 meters of water depth, a TLP will typically have 8 tendons. However, at 2400 meters (i.e., at double the depth), the number of tendons for a similar TLP ("similar" TLP but not "identical", because at increased depth some of the design features of the TLP are different, and the TLP system weight become more dominated by the weight of the tendons) may increase by order of magnitude (i.e., 80 tendons, by rough model calculations). Or in other words, increasing the depth by 2 times, increases the tendons by about 10 times. Generally, cost and space limitations make application of more than about 20 tendons to a TLP impractical.

In addition to the use of spars for ultradeep water, several other alternative DVA concepts have been proposed.

One of these is the buoyant leg structure (International Design Engineering and Analysis Services, Inc, San Francisco, CA) which is a shorter spar with a tether. However, this concept cannot easily be extended to large waterdepth because the tendon size increases significantly with waterdepth, and is cost-prohibitive beyond 5,000 ft.

Another of these is the TPG3300 (Technip-Coflexip, Paris, France), a deep draft semi-submersible. However, because of stability requirements, this concept requires a very large displacement and therefore its cost is veryhigh, comparable to a spar, and its motion characteristics are such that very large riser tensionners are required to preserve integrity of the risers.

Even another of these is the minDOC (minDOC, LLC, New Orleans, LA), a spar-like structure with smaller

multiple columns. This concept has a better Vortex-Induced Vibrations (VIV) performance than a spar, however, due to the complexity of the hull, its cost is very high.

Still another of these is the ABB spar (ABB Lummus Global, Inc, Houston,TX), which is a short spar with a very large diameter. This concept also suffers from VIV, and due to the large buoyancy near the water line, it experiences very large current and drift forces, and the requirements on the mooring systems are excessive. It is not a better alternative than a spar.

Thus, in spite of the advancements in the art, there still exists a need in the art for apparatus and methods for the exploration of, drilling of, and production from offshore subterranean reservoirs.

There is another need in the art for apparatus and methods for the exploration of, drilling of, and production from offshore subterranean reservoirs, which do not suffer from the disadvantages of the prior art apparatus and methods.

There is even another need in the art for apparatus and methods for the exploration of, drilling of, and production from offshore subterranean reservoirs in greater than 1500 meters of water depth.

These and other needs in the art will become apparent to those of skill in the art upon review of this specification, including its drawings and claims.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide for apparatus and methods for the exploration of, drilling of, and production from offshore subterranean reservoirs.

It is another object of the present invention to provide for the exploration of, drilling of, and production from offshore subterranean reservoirs, which do not suffer from the disadvantages of the prior art apparatus and methods.

It is even another object of the present invention to provide for the exploration of, drilling of, and production from offshore subterranean reservoirs in greater than 1500 meters of water depth.

These and other objects of the present invention will become apparent to those of skill in the art upon review of this specification, including its drawings and claims.

According to one embodiment of the present invention, there is provided an offshore platform. The

platform includes a deck for supporting hydrocarbon exploration, drilling or production equipment, a buoyant member, an open support structure positioned between the deck and buoyant member and connected to both, and a plurality of tendons connected to the buoyant member suitable for anchoring the platform. When the platform is positioned offshore, the deck is supported above the waterline, the upper end of the open structure is positioned above the water line, with the lower end positioned at least 100 feet below the waterline; and the heave resonance of the platform is at least 6 seconds.

According to another embodiment of the present invention, there is provided a method of exploring an offshore target zone for hydrocarbons. The method includes positioning a platform, as described above, offshore near the target zone. The method further includes conducting exploration activities from the platform.

According to even another embodiment of the present invention, there is provided a method of drilling for or

production of hydrocarbons from an offshore target zone. The method includes positioning a platform, as described above, offshore near the target zone. The method then includes conducting drilling or production activities from the platform.

These and other embodiments of the present invention will become apparent to those of skill in the art upon review of this specification, including its drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration of a typical traditional TLP 200, showing deck 10, buoyancy section 203, and tendons 204.

FIG. 2 is an illustration of one embodiment of Soft TLP 300 of the present invention, showing deck 10, support section 301, buoyancy member 303, and tendons 305.

FIG. 3 is an illustration of a typical traditional truss step spar 100, showing deck 10, spar 101 having a buoyant upper section 102 and a ballast lower section 103, truss section 105, and ballast section 109.

FIG. 4 is a detailed illustration of buoyant section 303 and columns 304.

FIGs. 5-11 show a typical installation sequence for the Soft TLP of the present invention.

FIG. 12 is a table showing the payload weights of the various major components for the proposed Soft TLP and the Brutus TLP, as utilized in the computer model for the comparison of Example 1.

FIGs. 13 and 14 are a table and graph, respectively, showing the results of the computer model comparison of Example 1 for the proposed Soft TLP of the present invention, and the commercial Brutus TLP.

DETAILED DESCRIPTION OF THE INVENTION

The apparatus of present invention is a modified version of the standard TLP, and is sometimes referred to herein as "Soft TLP."

The apparatus of the present invention will first be discussed in contrast to the typical TLP and to the typical truss step spar. Referring now to FIGs. 1, 2, and 3, there are shown, respectively, a typical TLP 200 (FIG. 1), the Soft TLP 300 of the present invention (FIG. 2), and the traditional truss step spar 100 (FIG. 3).

In FIGs. 1, 2 and 3, a conventional deck 10 is shown supported by, respectively, conventional TLP 200, Soft TLP 300 of the present invention, and spar 100.

Conventional prior art TLP further includes a buoyancy structure 203, a bottom anchoring structure (not shown) on the sea floor, and a plurality of tension elements 204 extending between the buoyancy structure and the bottom anchoring structure. Notice that with the conventional TLP, the buoyancy structure 203 provides a

large cross-section at the water level, subjecting TLP 200 to strong wave forces.

Conventional prior art spar 100 further includes spar buoy 101 having a highly buoyant upper section 102, and a lower portion 103 containing considerable ballast to lower the center of gravity of spar buoy 101. As spar 100 is a "truss spar," lower section of spar 101 is truncated, and replaced by truss structure 105 with horizontal plates 107 to reduce the platform motion. Further ballast section 109 is positioned at the far end of truss structure 105. Mooring lines 108 serve to anchor spar 100. Like conventional TLP 200, spar 100 provides a large surface area at the water level, thus subjecting spar 100 to strong wave forces.

Focusing now on the Soft TLP 300 of the present invention attention is directed to FIG. 1 and additionally to FIG. 4 a detailed illustration of buoyant section 303 and columns 304.

In the practice of the present invention, deck 10 may be any deck as is known in the art. Deck 10 may

include separate or integrated modules, compartments or sections for drilling, production, quarters, and/or utilities.

This deck 10 rests upon and is supported by support structure 301, which includes a suitable number of columns 304, and reinforcing members 302. In the practice of the present invention, Soft TLP 300 will generally includes at least 1 column 304, preferably at least 2, more preferably at least 3, and even more preferably at least 4 columns 304. Any suitable number of reinforcing members are utilized to provide the desired stability. Columns 304 and reinforcing members 302 are designed generally to reduce, more preferably to minimize the effect of the waves upon Soft TLP 300.

Buoyant section 303 provides the necessary buoyancy to support Soft TLP 300. This buoyant section 303 is positioned at the end of columns 304, with the length of columns 304 selected to generally position buoyant section at least 100 feet below the mean waterline, more preferably at least 150 feet below the mean waterline,

and even more preferably at least 200 feet below the mean waterline, an still even more preferably at least 250 feet below the mean waterline.

Optional extension members 307 extend from each corner of buoyant member 303, and provide increased pitch stiffness.

As compared to a conventional TLP or spar system, Soft TLP 300 exposes a much smaller surface area to wave forces in the first 100 feet of water depth. Columns 304 and reinforcing members 302 are generally designed to minimize their surface area. Buoyant section 303 is generally positioned below the first 100 feet of water depth.

In the practice of the present invention, any suitable tendon may be utilized as tendons 305, and such tendons 305 are secured to buoyant section 303 and the ocean bottom as is known in the art.

In the practice of the present invention, the Soft TLP is anchored with sufficient stiffness so that the Soft TLP will have a heave resonance generally near the

lower end of the 6 to 15 second range. Preferably, heave resonance range for the Soft TLP will generally have an upper end of about 12 seconds, preferably about 10 seconds, and more preferably about 8 seconds, and still more preferably about 7 seconds, and a lower end generally about 6 seconds, preferably greater than 6 seconds, and more preferably about 7 seconds. The prefered heave resonance range for the soft TlP is about 6 to about 10 seconds, preferably about 7 to about 9 seconds, and more preferably about 7 to about 8 seconds.

Referring now to FIGs. 5-11, there is shown the installation sequence for the Soft TLP of the present invention. Referring first to FIG. 5, the hull, comprising buoyant section 303 and support section 301 is towed to the desired location. Referring next to FIG. 6 the hull is then ballasted to below the ultimate desired target depth (which in FIG. 6 is shown as 220 feet of water depth). Referring next to FIG. 7, tendons 305 are assembled by a construction vessel as is known in the art. Referring next to FIG. 8, tendons 305 are passed to

the hull and pre-connected. Referring next to FIG. 9, all tendons 305 are connected and tensioned, and buoyant section 303 is partly de-ballasted. Referring next to FIG. 10, deck 10 is assembled onto the hull. Referring next to FIG. 11, deck 10 is complete, and buoyant member 303 is fully de-ballasted.

EXAMPLES

The following examples have been provided merely to illustrate a few embodiments the invention, and are not intended to, and do not limit the scope of the claims.

Example 1: Comparison of Soft TLP (proposed design) to an actual TLP

In this Example, a computer model comparison is made between a proposed Soft TLP design of the present invention and an actual TLP, the Shell Brutus TLP, located in Green Canyon Block 158 in 2,985 feet of water in the Gulf of Mexico.

The payload weights of the various major components for the proposed Soft TLP and the Brutus TLP, as utilized in the computer model are shown in FIG. 12.

The platform response was computed using the Shell Oil Company in-house numerical tool COSMOS (software to compute the response of floating offshore platforms).

COSMOS is a fully-coupled finite-element program that predicts the response (platform motion, mooring line or tendon tension) of various floating systems and considers the interaction between mooring lines or tendons dynamic tensions and the floating vessel. Diffraction-radiation theory is used to compute wave loads, and Morison equation to model viscous effects. A dynamic wind model is used to predict wind loads. The response of the platform is computed in a 100 year hurricane, and cumulative tendon damage is determined using an annual wave-scatter diagram.

Results are presented in FIGs. 13 and 14.

While the illustrative embodiments of the invention have been described with particularity, it will be understood that various other modifications will be apparent to and can be readily made by those skilled in the art without departing from the spirit and scope of the invention. Accordingly, it is not intended that the scope of the claims appended hereto be limited to the examples and descriptions set forth herein but rather that the claims be construed as encompassing all the features of patentable novelty which reside in the present invention, including all features which would be treated as equivalents thereof by those skilled in the art to which this invention pertains.